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## How a Substation Happens

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### 1.1 Background

The construction of new substations and the expansion of existing facilities are commonplace projects in electric utilities. However, due to the complexity, very few utility employees are familiar with the complete process that allows these projects to be successfully completed. This chapter will attempt to highlight the major issues associated with these capital-intensive construction projects, and provide a basic understanding of the types of issues that must be addressed during this process.

There are four major types of electric substations. The first type is the switchyard at a generating station. These facilities connect the generators to the utility grid and also provide off-site power to the plant. Generator switchyards tend to be large installations that are typically engineered and constructed by the power plant designers and are subject to planning, finance, and construction efforts different from those of routine substation projects. Because of their special nature, the creation of power plant switchyards will not be discussed here, but the expansion and modification of these facilities generally follow the routine processes.

Another type of substation is typically known as the customer substation. This type of substation functions as the main source of electric power supply for one particular business customer. The technical requirements and the business case for this type of facility depend highly on the customer's requirements, more so than on utility needs, so this type of station will also not be the primary focus of this discussion.

The third type of substation involves the transfer of bulk power across the network and is referred to as a switching station. These large stations typically serve as the end points for transmission lines originating from generating switchyards, and they provide the electrical power for circuits that feed distribution stations. They are integral to the long-term reliability and integrity of the electric system and enable large blocks of energy to be moved from the generators to the load centers. Since these switching stations are strategic facilities and usually very expensive to construct and maintain, these substations will be one of the major focuses of this chapter.

The fourth type of substation is the distribution substation. These are the most common facilities in electric power systems and provide the distribution circuits that directly supply most electric customers.

They are typically located close to the load centers, meaning that they are usually located in or near the neighborhoods that they supply, and are the stations most likely to be encountered by the customers. Since the construction of distribution stations creates the majority of projects in utility substation construction budgets, these facilities will be the other major focus of this chapter.

## **1.2 Needs Determination**

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An active planning process is necessary to develop the business case for creating a substation or making major modifications. Planners, operating and maintenance personnel, asset managers, and design engineers are among the various employees typically involved in considering such issues in substation design as load growth, system stability, system reliability, and system capacity, and their evaluations determine the need for new or improved substation facilities. Customer requirements, such as a new factory, etc., should be considered as well as customer relations and complaints. In some instances, political factors also influence this process, such as when reliability is a major issue. At this stage, the elements of the surrounding area are defined and assessed, and a required in-service date is established. The planning process produces a basic outline of what is required in what area.

## **1.3 Budgeting**

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Having established the broad requirements for the new station — such as voltages, capacity, number of feeders, etc. — the issue of funding must be addressed. This is typically when real estate investigations of available sites begin, since site size and location can significantly affect the cost of the facility. Preliminary equipment layouts and engineering evaluations are also undertaken at this stage in order to develop ballpark costs, which then have to be evaluated in the corporate budgetary justification system. Preliminary manpower forecasts for all disciplines involved in the engineering and construction of the substation should be undertaken, including identification of the nature and extent of any work that the utility may need to contract out. This budgeting process will involve evaluation of the project in light of corporate priorities and provide a general overview of cost and other resource requirements. Note that this process may be an annual occurrence. Any projects in which monies have yet to be spent are generally reevaluated during every budget cycle.

## **1.4 Financing**

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Once the time has arrived for work to proceed on the project, the process of obtaining funding for the project must be started. Preliminary detailed designs are required in order to develop firm pricing. Coordination between business units is necessary to develop accurate costs and to develop a realistic schedule. This may involve detailed manpower forecasting in many areas. The resource information has to be compiled in the format necessary to be submitted to the corporate capital estimate system, and internal presentations must be conducted to sell the project to all levels of management.

Sometimes it may be necessary to obtain funding to develop the capital estimate. This may be the case when the cost to develop the preliminary designs is beyond normal departmental budgets, or if unfamiliar technology is expected to be implemented. This can also occur on large, complex projects or when a major portion of the work will be contracted. It may also be necessary to obtain early partial funding in cases where expensive, long-lead-time equipment may need to be purchased, such as large power transformers.

## **1.5 Traditional and Innovative Substation Design**

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Traditionally, high-voltage substations are engineered based on established layouts and concepts and conservative requirements. This approach can restrict the degree of freedom in introducing new solutions.

The most that can be achieved with this approach is the incorporation of new primary and secondary technology in preengineered standards.

A more innovative approach is one that takes into account functional requirements such as system and customer requirements and develops alternative design solutions [1]. System requirements include elements of rated voltage, rated frequency, system configuration present and future, connected loads, lines, generation, voltage tolerances (over and under), thermal limits, short-circuit levels, frequency tolerance (over and under), stability limits, critical fault clearing time, system expansion, and interconnection. Customer requirements include environmental consideration (climatic, noise, aesthetic, spills, right-of-way), space consideration, power quality, reliability, availability, national and international applicable standards, network security, expandability, and maintainability.

Carefully selected design criteria could be developed to reflect the company philosophy. This would enable consideration and incorporation of elements such as life-cycle cost, environmental impact, initial capital investment, etc. into the design process. Design solutions could then be evaluated based on established evaluation criteria that satisfy the company interests and policies.

## 1.6 Site Acquisition

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At this stage, a footprint of the station has been developed, including the layout of the major equipment. A decision on the final location of the facility can now be made, and various options can be evaluated. Final grades, roadways, storm-water retention, and environmental issues are addressed at this stage, and required permits are identified and obtained. Community and political acceptance must be achieved, and details of station design are negotiated in order to achieve consensus. Depending on local zoning ordinances, it may be prudent to make settlement on the property contingent upon successfully obtaining zoning approval, since the site is of little value to the utility without such approval. It is not unusual for engineering, real estate, public affairs, legal, planning, operations, and customer service personnel — along with various levels of management — to be involved in the decisions during this phase.

The first round of permit applications can now begin. While the zoning application is usually a local government issue, permits for grading, storm water management, roadway access, and other environmental or safety concerns are typically handled at the state or provincial level, and they may be federal issues in the case of wetlands or other sensitive areas. Other federal permits may also be necessary, such as those for aircraft warning lights for any tall towers or masts in the station. Permit applications are subject to unlimited bureaucratic manipulation and typically require multiple submissions and could take many months to reach conclusion. Depending on the local ordinances, zoning approval may be automatic or may require hearings that could stretch across many months. Zoning applications with significant opposition could take years to resolve.

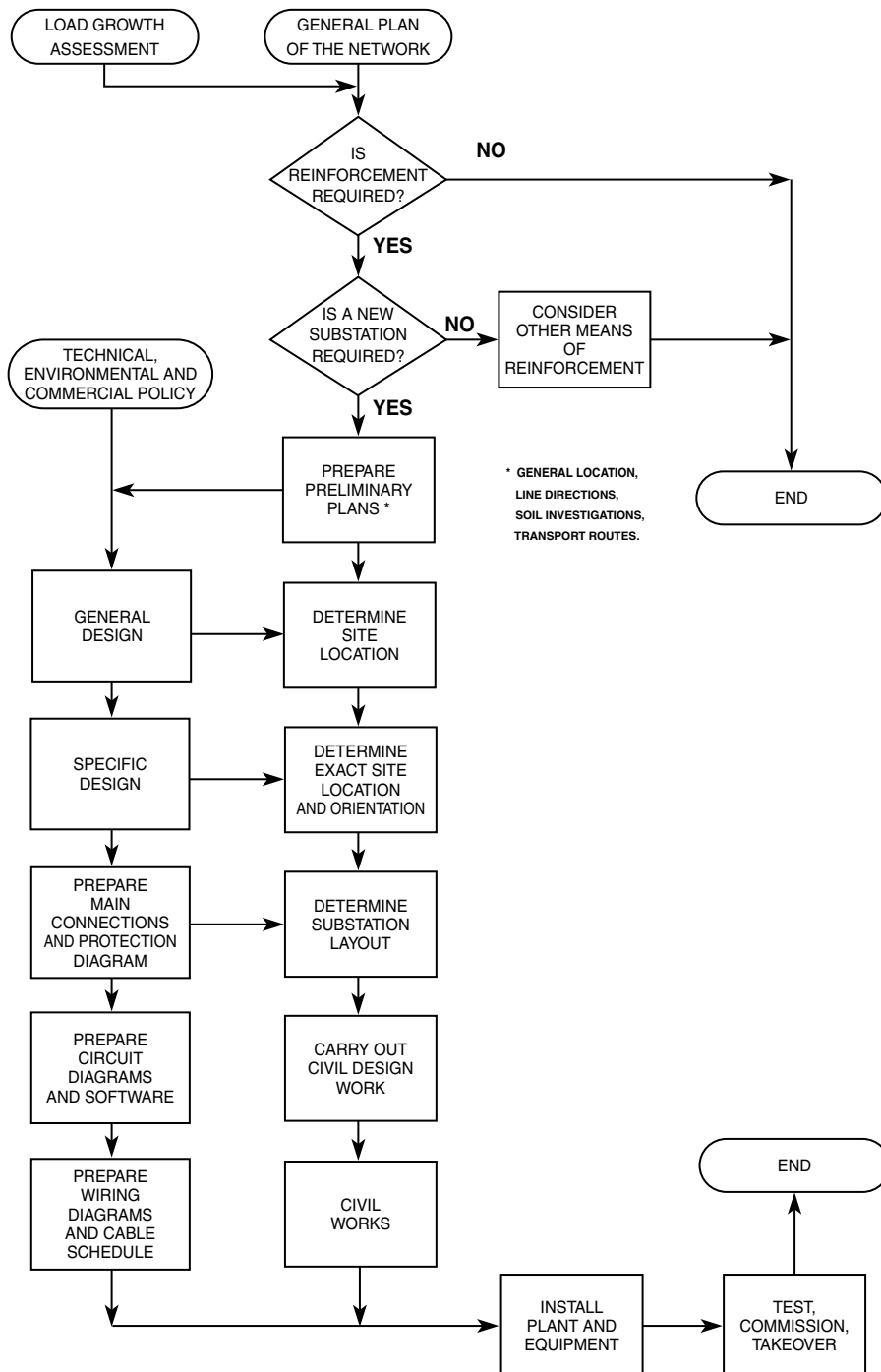
## 1.7 Design, Construction, and Commissioning Process

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Once the site location has been selected, the design, construction, and commissioning process would broadly follow the steps shown in [Figure 1.1](#) [2]. Recent trends in utilities have been toward sourcing design and construction of substations through a competitive bidding process to ensure capital efficiency and labor productivity.

### 1.7.1 Station Design

Now the final detailed designs can be developed along with all the drawings necessary for construction. The electrical equipment and all the other materials can now be ordered and detailed schedules for all disciplines negotiated. Final manpower forecasts must be developed and coordinated with other business units. It is imperative that all stakeholders be aware of the design details and understand what needs to be built and when it needs to be completed to meet the in-service date. Once the designs are completed and the drawings published, the remaining permits can be obtained.



**FIGURE 1.1** Flow chart illustrating steps involved in establishing a new substation [3].

### 1.7.2 Station Construction

With permits in hand and drawings published, the construction of the station can begin. Site logistics and housekeeping can have a significant impact on the acceptance of the facility. Parking for construction personnel, traffic routing, truck activity, trailers, fencing, lack of mud and dirt control, along with trash and noise can be major irritations for neighbors, so attention to these details is essential for achieving community acceptance. All the civil, electrical, and electronic systems are installed at this time. Proper attention should also be paid to site security during the construction phase, not only to safeguard the material and equipment, but also to protect the public.

### 1.7.3 Station Commissioning

Once construction is complete, testing of various systems can commence and all punch-list items can be addressed. Environmental cleanup must be undertaken before final landscaping can be installed. Note that, depending upon the species of plants involved, it may be prudent to delay final landscaping until a more favorable season in order to insure optimal survival of the foliage. Public relations personnel can make the residents and community leaders aware that the project is complete, and the station can be made functional and turned over to the operating staff.

## References

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3. CIGRE (Conseil International des Grands Reseaux Electriques) Brochure Nr. 161, *General Guidelines for the Design of Outdoor AC Substations*, August 2000, WG 23-03.